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WAR MEDICINE AND SURGERY

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COMPOUND FRACTURES.

In the war of 1914-1918 compound fractures made up about 30% of the serious wounds sustained, and were, therefore, the most frequent type of major injury with which the Army surgeons had to deal. Figures for the present war are not readily available, but one would not expect them to be significantly different. Of about 250 patients admitted to the Naval Hospital after the raid on Pearl Harbour, 10% had compound fractures. The relative number of fractures, in this instance, was reduced somewhat by a preponderance of cases of burns.

More than half of the compound fractures of wartime occur in the lower limb, and most of the remainder in the upper limb. Consequently the following account is limited to fractures in these two sites.

First Aid.

The first-aid measures consist in the treatment of hæmorrhage and shock, and the splinting of the fracture. This latter step is not entirely distinct from the others, since immobilization of the limb is an important means of reducing pain and exudation, both of which produce shock.

Hæmorrhage can usually be stopped by firmly pressing a pad on the bleeding point. The pad is then bandaged accurately into position. Tourniquets are very seldom indicated, but, if one is used, a letter "T" should be marked on the patient's forehead, so that the tourniquet will not be forgotten. The pneumatic type is the one least likely to cause compression injuries of nerves and soft tissues.

In order to minimize the effects of shock, the patient should be kept warm, and, as far as possible, relieved of pain. He should also be reassured, and given fluids by mouth. Shock tends to progress with acceleration, and this enhances the importance of early prophylaxis. Very simple treatment given as a first-aid measure may be as valuable as major therapeutic procedures undertaken later.

There are various ways of immobilizing any given fracture temporarily; some of the methods have been previously described in this series of articles.[1] The use of the Thomas splint should be specially stressed, however, since it is vastly superior to all rivals as a first-aid splint for fractures of the femur or upper part of the bones of the leg. After its introduction during the Great War, the death rate from gunshot fractures of the femur dropped from about 70% to about 40%; figures given for the decrease differ widely, but no one doubts that the reduction was spectacular.

Three attendants are required to apply a Thomas splint satisfactorily. The full drill has been well described,[2] and the following is only a brief statement of the general procedure. The first man supports the limb at the fracture site. The second maintains extension on the limb, first by grasping the foot, and later by means of a clove-hitch halter, or a metal pin passed through the boot, or, best of all, by means of a Millbank clip. The third man applies the Millbank clip or other device, slips on the splint, fastens the extension cords, and ties three bandages that support the posterior part of the limb, and one bandage that fastens the limb down to the splint. He then applies Gooch splinting to the fracture site. Lateral movements are not possible when the Millbank clip is used, and in the other cases they are prevented by means of a special stirrup fastened to the splint. The whole splint is finally slung to the suspension bar of the stretcher.

The question has been raised as to whether extension should be applied when a fragment of a bone such as the femur projects from a wound, and is obviously contaminated. Extension would cause the fragment to be pulled back through the skin and to smear organisms over the lacerated tissue. This is a danger, but in general the risk must be taken, since the danger from shock, caused by movement at the fracture site, is even greater. An exception to this rule may be made when a surgical centre is near by.

In some circumstances sulphonamide microcrystals may be available at the place where the casualty is first treated. If so, a mixture of two parts of sulphanilamide and one of sulphathiazole should be liberally sprinkled over the wound.

General Treatment at Hospital.

Whenever a patient has a compound fracture of a long bone, it can be safely assumed that he will suffer from traumatic shock, unless preventive treatment is begun early. There is no need to wait for the development of the classical signs and symptoms of shock; to do so is to lose valuable time. The patient should be given an injection of morphine, adequate to abolish his pain, and be examined to see that hæmorrhage has been controlled. It is now generally recognized, however, that reduction of effective blood volume, through the loss of blood or plasma and the dilatation of capillaries, is the most important cause of shock. Therefore, plasma, serum, or human albumin solution should be administered at once. Blood is almost as valuable, but sometimes more troublesome to obtain. The most reliable guide to the dosage is the systolic blood pressure, which should be maintained above 100 millimetres of mercury. The initial dose of about one-half to one litre is, however, given if possible before any fall in blood pressure has occurred. In 100 cases of shock, specially studied by the Medical Research Council's Committee on Traumatic Shock, the total amount of fluid transfused varied from half a litre to seven litres. If transfusion can be given early there is less likelihood of having to use the enormous wasteful doses of five to fifteen litres that are reported from time to time. The speed at which the fluid is given depends on whether the clinical signs of shock are established or not. If the blood pressure has fallen below 100 millimetres of mercury and the patient can tolerate a quick transfusion, the fluid is administered at the rate of one litre in twenty to thirty minutes; otherwise, it is an advantage to use a slower rate. Further, after the first dose, it is preferable to give small amounts of 300 to 500 cubic centimetres about every four to six hours, unless a sudden drop in blood pressure occurs and calls for more urgent treatment. If the patient does not respond at all to the first litre or so, the prognosis is unfavourable.

Other measures in the treatment of shock are rest, the maintenance of body temperature by means of moderate

heat, and in severe cases the administration of oxygen. The surgeon has to use his judgement in order to decide to what extent the unreduced fracture is responsible for maintaining shock. In some cases it may be permissible for him to operate before resuscitation is complete, but never before it has been commenced.

Preliminary Assessment.

Radiographs are regularly taken both to show the extent of the damage to bone, and to give concrete evidence of retained foreign bodies. Fissuring of the bone should be noted, and involvement of a joint introduces a very important complication. The search for foreign bodies is particularly necessary if the injury is known to have been caused by a missile, and there is no wound of exit. In making the clinical examination the surgeon should look for signs of injury to blood vessels, nerves and tendons as well as to soft tissues and bone. Injury to the muscles and tendons is, of course, difficult to detect at this stage.

In general, the surgeon is faced with three possible courses of action when he has treated the patient for shock and made an examination of the injury: (*a*) if the stage of infection has not been reached, he should excise the wound; (*b*) if the wound is infected, he should undertake *débridement*; and (*c*) in a few cases amputation is indicated; the necessity for amputation may not become apparent until the wound has been explored.

Wound Excision.

After the patient has been anæsthetized, the affected limb is given a preliminary cleaning. To do this the wound is covered with a dry sterile dressing and the surrounding skin is washed thoroughly with soap and warm water, and shaved as close up to the wound edges as possible. Care is taken that the washings pass away from, and not into, the wound. This stage is quite important, and, in the absence of a reliable assistant, it should not be beneath the dignity of the surgeon to do it himself.

Some surgeons[6] then wash the wound itself with plain white soap and warm water, applied by means of soft cotton wool. This is done on the ground that, no matter how thorough the surgeon intends to make the subsequent excision, he must always leave intact certain essential structures, and it is an advantage to wash these. After the soap and water have been used, every recess of the wound is thoroughly irrigated with warm sterile salt solution.

Even if the surgeon does not wash the actual wound, he should rewash the edges and remove superficial gross contamination before he begins the excision. He may also paint the surrounding skin with antiseptic. Further, it is usually much simpler to operate expertly on the thigh if extension is applied beforehand. The excision is done layer by layer, and sharp scalpels rather than scissors are used.

Skin should not be sacrificed needlessly, for it recovers well and is invaluable during healing. The skin edge is seized with toothed forceps and a narrow strip usually about two to three, and rarely more than ten, millimetres wide is excised from the margin of the wound. The wound is then enlarged by incisions made in the long axis of the limb, and the sides are retracted to give a generous exposure. Additional superficial gross particles are removed and the instruments are changed.

Deep fascia is very liable to prevent subsequent drainage. It should therefore be freely opened up by longitudinal incisions, and partly excised. Subfascial hæmatomata are then evacuated.

The cut ends of muscles are liable to retract into their sheaths. The muscles must therefore be verified as excision proceeds. The guide as to when sufficient tissue has been removed is that the remaining muscular tissue should bleed when cut and twitch when stimulated. Muscles such as the sartorius and gracilis receive most of their blood supply from the distal end, so that, if the middle is damaged, the whole muscle must usually be removed in order to avoid massive gangrene. This sign of bleeding from the cut muscle surface is not available to surgeons who use a tourniquet to secure a bloodless field, and such operators may have difficulty in distinguishing living from dead tissue.

Samples of the tissue excised, particularly of the contaminated parts of the muscles, should be placed in a sterile container, so that they can be examined for the presence of gas gangrene organisms. If this is done as a routine, early warning may be received of wounds that subsequently develop gas gangrene. Of course, not all the wounds contaminated by the appropriate organisms develop gas gangrene.

Detached bone fragments must be removed. This sometimes makes it necessary to approach the fracture from both sides, for, when a missile has perforated a bone, many splinters are carried in a direction away from the wound of entrance. Removal of whole segments of the shaft of the bone is avoided, if possible, and fragments with periosteal or muscle attachments are preserved. Pulped medulla must be removed and some bone fragments may have to be sacrificed in order to get a good exposure of the medullary cavity. Soiled fracture ends are nibbled off with heavy bone-cutting forceps.

Neurovascular bundles must be left intact, and therefore a detailed knowledge of anatomy is required in order to operate on deep wounds.

Just as most English surgeons avoid the preliminary washing of the wound itself, so they refrain from using irrigation when the excision has been started. In America, however, it is common to irrigate the wound with five to ten litres of warm sterile normal saline solution before completing the excision. The nozzle of the irrigator should be passed right to the depths so that the fluid wells up from within, rather than washes in contamination from without. The irrigation brings into view long filaments of tissue with inadequate blood supply, and these should be removed.

Severed nerves and tendons may be brought into contact, though no formal attempt is made to suture them. Exposed bone has a very low resistance to infection and should be covered by muscle if this is possible. Before concluding the excision, the operator should look carefully over the wound, and appraise the viability and cleanliness of the walls. He must also ensure hæmostasis. Fine-grade silk or cotton is used for any ligatures required, since absorbable material promotes a tissue reaction which is favourable to infection. Under war conditions compound fracture wounds are never closed by primary suture, nor is a distinction made between fractures compounded from without and those compounded from within.

At the conclusion of the excision five to ten grammes of sterile sulphonamide powder are sprinkled throughout the wound. The local use of sulphonamide has been said to mark the greatest progress in the history of the treatment of compound fractures. In order to correct this overstatement it is worth while recalling the progress that occurred in the treatment of compound fractures before the use of sulphonamides. The record is summarized in Table I, which is a modified account of some published figures.

TABLE I.
Showing Progress in the Treatment of Compound Fractures.

Surgeons in Charge.	Number of Patients.	Years for which Statistics were Collected.	Mortality Rate.	Percentage of Patients Requiring Secondary Amputation.
Billroth	219	1860–1867	60%	20%
Zürich Clinic ..	675	1899–1929	15%	18%
Böhler and Ehalt..	307	? –1937	4%	5%

On the other hand, there is fairly good evidence that the local use of sulphonamide is a useful adjunct to other measures. Such a conclusion is suggested by Table II, which is adapted from the literature.

If sulphonamide is used as a local application only, the drug is completely absorbed within a few days. It is therefore given both orally and locally. The initial oral dose is four grammes, and this is followed by four grammes per day for four days. At the end of the fourth

ILLUSTRATIONS TO THE ARTICLE BY DR. W. S. DAWSON AND DR. O. LATHAM.

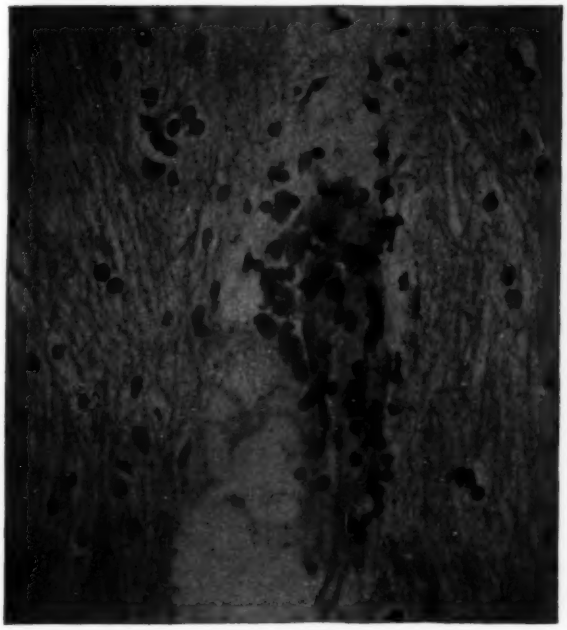

FIGURE I.

Mononuclear cells and *Gitterzellen* round a blood vessel—evidence of tissue destruction (medulla; × 200).

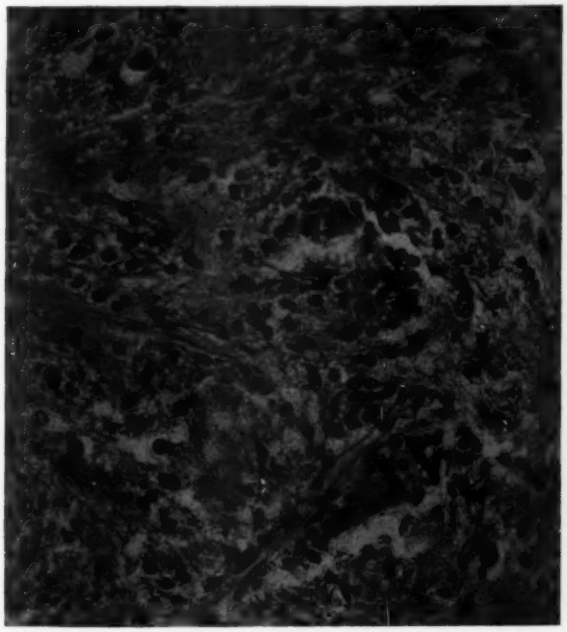

FIGURE II.

Obliterated capillaries near vagal nuclei (medulla; × 200).

FIGURE III.

Dense perivascular glia round medium-sized blood vessel (medulla; × 200). Phosphotungstic hæmatoxylin stain. In the section the outer violet glia can be differentiated from the red mesenchyme.

FIGURE IV.

Part of Figure III enlarged. The perivascular glia and other parts including the olives hold large glial cells (G) and they enmesh a neurone at N (× 400).

ILLUSTRATIONS TO THE ARTICLE BY DR. J. B. THIERSCH.

FIGURE I.
Case I: Adrenal cortex in the sternal bone marrow ten days after implantation.

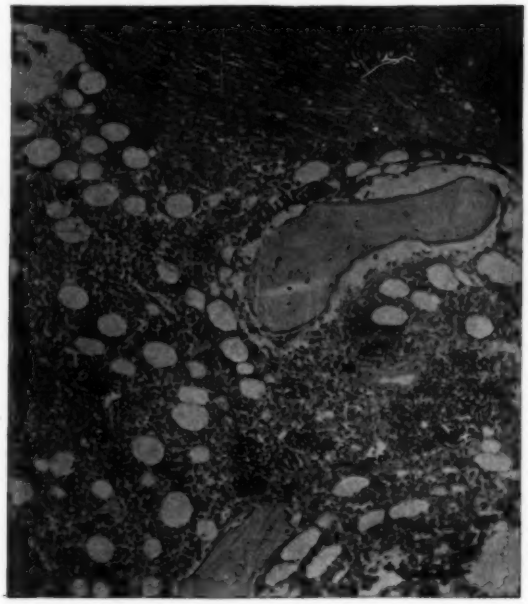

FIGURE II.
Case II: Adrenal cortex in the sternal bone marrow ten days after implantation.

ILLUSTRATIONS TO THE ARTICLE BY DR. A. T. EDWARDS AND DR. O. LATHAM.

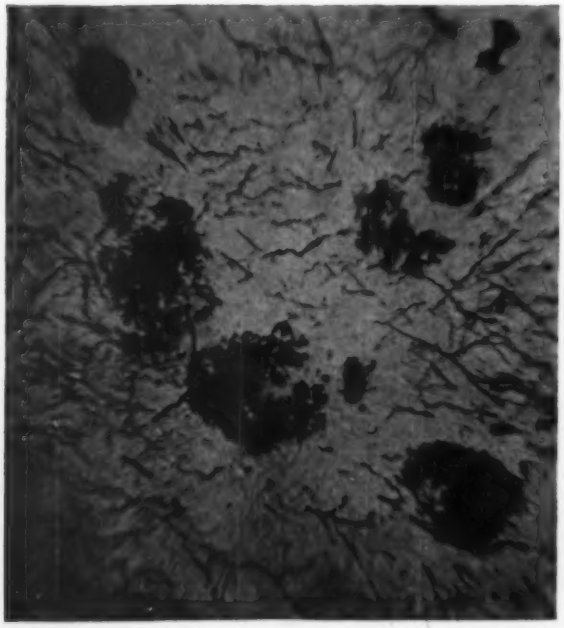

FIGURE I.
Preparation showing argentophile plaques by von Braunmühl's method (× 100).

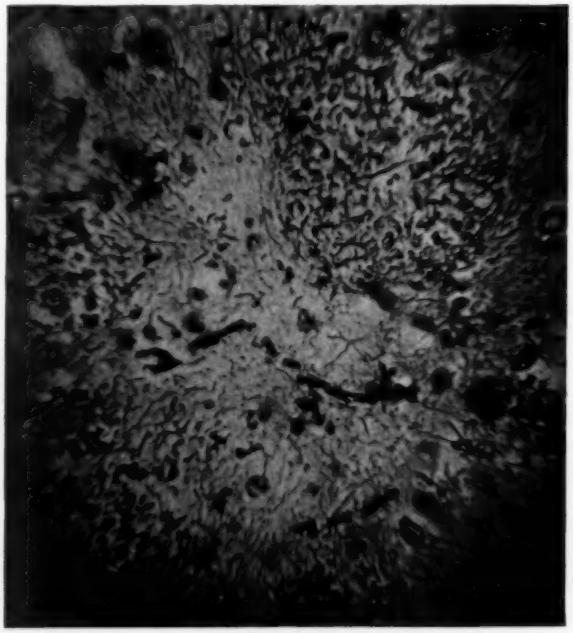

FIGURE II.
Preparation showing four plaques round a vessel by the Foot-Rogers method (× 200). They resemble a collection of commas.

TABLE II.

Showing Results of Various Types of Treatment for Compound Fractures.

Type of Treatment.	Number of Patients.	Mortality Rate.	Patients who Developed Pyogenic Infection.	Patients who Developed Gas Bacillus Infections.	Patients who Required Secondary Amputation.	Average Stay in Hospital in Days.
Débridement	50	6%	54%	10%	10%	38
Débridement + prophylactic X-ray treatment..	57	Nil	16%	Nil	Nil	20
Débridement[1] + sulphonamide given locally ..	54	Nil	6%	Nil	Nil	7

[1] Eleven of these patients had their fractures treated by internal fixation. "*Débridement*" is probably used, as frequently happens, in the sense of "excision."

day the dose is reduced; at the end of the tenth day administration of the drug is discontinued if the temperature has become normal.

Reduction and Immobilization.

In general, reduction should not be attempted until excision of the wound is complete, for the surgeon may find it difficult to gauge the extent of the excision required if the fracture is reduced early.

There are various methods and combinations of methods for securing and maintaining reduction, but the most important are: (*a*) manipulation and manual traction followed by external fixation with plaster; (*b*) traction and counter-traction; (*c*) internal fixation, with which is combined some form of simple external fixation; and (*d*) mechanical fixation. These will be briefly discussed in turn.

Manipulation and manual traction followed by external fixation with plaster are a successful conservative method of treating many compound fractures. It is the method of choice, but while it works well with most fractures of the upper limb, it is not usually adequate for those of the lower limb. In particular, the general experience of this war shows that many fractures of the femur cannot be maintained in position by plaster alone. Trueta claims that certain compound fractures may be safely immobilized in plaster, when this would not be possible for a simple fracture in the corresponding site. His explanation is that the process of excision of the wound, carried out during the treatment of compound fractures, reduces both the tone and the substance of the muscle mass. Trueta sometimes uses skeletal traction during the operation to obtain reduction, but, apparently, he does not incorporate the traction pins in the cast.

The plaster is usually put on while the patient is under the anæsthetic. It is unpadded except in the region of bony prominences. Apart from the difficulty in maintaining reduction, the method has some disadvantages such as a liability to cause gangrene and pressure sores, but, on the other hand, patients rapidly lose their pain and toxæmia, and healing proceeds well.

Traction and counter-traction may be associated with the closed plaster method by incorporating Kirschner's wire or Steinmann's pin into the cast. The pin or wire is often inserted before the wound excision is commenced, so that traction may be maintained throughout the operation. Some form of orthopædic table is necessary for this method, and so it is often not available in wartime. An alternative is to use continuous traction applied by means of various forms of frames and splints. The traction is named according to the part of the limb through which it is applied—skeletal, skin or, occasionally, pulp.

Internal fixation by plates and screws, as used by Lane, fell into universal disrepute as a treatment for compound fractures, on account of the frequency with which it caused infection. The method has recently been revived, however, as a result of two improvements on the old technique. The first is the use of sulphonamides, which decrease the liability to any infection; the second is the introduction of vitallium, a non-ionizable alloy which causes little or no bone reaction. Some simple form of external fixation, such as the plaster cast or Thomas splint, is required in conjunction with the internal fixation.

The method has won little support in England, and many surgeons consider that it does not merit further trial, especially in wartime compound fractures. Watson-Jones has commented as follows on some results of the internal fixation technique used in an American clinic: (*a*) In the case of recent compound fractures there is the hope of easier management of the patients and a smaller number of malunions, but the risk of infection is considerably increased. (*b*) If wound infection is established when the fracture is first seen, the use of internal fixation is positively dangerous. (*c*) In the case of old compound fractures with persistent draining sinuses, the results are fairly good if the sequestra are removed and the bone is plated; but results equally as good can be obtained with sequestrectomy followed by complete and uninterrupted plaster immobilization. (*d*) Metallic internal fixation is satisfactory, under the control of sulphonamide, when the wounds have been healed for at least one year, and there is no more than potential infection present.

It must be emphasized that, in any case, the use of internal fixation is not an easy way of treating a fracture; its apparent simplicity is fallacious. Anyone who attempts to use this method should be familiar with the principles of bone and joint surgery, and should have a thorough knowledge of anatomy. Otherwise, he invites disaster.

A further method that is being used for the reduction and fixation of fractures, including compound fractures, is the method of mechanical fixation.[2][3] The principle is that pins or screws are fastened into the bone fragments above and below the fracture, and are then used in the mechanical manipulation of the fracture into correct position. Once the reduction has been obtained, the pins or screws of the two fragments are joined by bars, so that the whole becomes one immovable unit bridging the fracture site. Haynes and Roger Anderson have each devised suitable apparatus for this work.

The disadvantages of this method are threefold: the danger of infection starting along the track of the pins; the danger of fixing the fragments in a position of distraction; and the difficulty which is experienced, at first, in manipulating the various levers, rotating bars and screws. On the other hand, the method provides a powerful and accurate means of reducing difficult fractures, a vice-like form of fixation, the opportunity for rapid healing, and the advantage of having the patient ambulant.

At the present time the method is being used for compound fractures when other methods show little promise of success. In cases in which the closed plaster treatment is likely to control the infection, but not the fracture, the method of mechanical fixation may be combined with the application of a plaster. Mechanical fixation should not, at present, be used in compound fractures which can be satisfactorily handled by conservative treatment. The main indications for mechanical fixation are: (*a*) comminuted or oblique compound fractures in which fixation is difficult to obtain; (*b*) fractures in badly shocked patients when it is desirable to accomplish and maintain at least partial reduction without moving the patient from his bed; and (*c*) fractures in old debilitated patients who cannot withstand long immobilization in bed.

Treatment of Late Cases of Fracture.

Excision of a wound associated with a compound fracture should not be attempted later than about twenty-four hours after the time of wounding. This time interval is arbitrary and may possibly be extended by the first-aid use of a sulphonamide. It is, however, disastrous to attempt to excise a wound that has become infected—the

infection merely spreads. The only operative treatment required for such infected wounds is *débridement*, that is, the opening up of the wound to promote drainage and the removal of accessible foreign bodies. Loose fragments of bone are also removed and sufficient opening is made in the bone to allow the medullary cavity to drain. Drainage tubes are not employed except in a few cases in which the muscle mass makes normal drainage unlikely. The wound is lightly packed with "Vaseline" gauze.

The second stage in the treatment is usually the application of a plaster cast. It may not be possible to secure an accurate reduction of the fracture by this means, but it is more important to deal with the infection first; if necessary, better alignment can be obtained when the plaster is changed. All patients with infected fractures are given full courses of sulphonamide by mouth.

The plaster technique is not used at once on those patients who have a fulminating infection. These are treated conservatively for a few days until the acute infection subsides. Their progress is watched carefully in case surgical interference becomes necessary to treat gas gangrene or a further localized area of pus.

Once a plaster cast has been applied, it is left unchanged for five or six weeks unless some complication occurs. A pyrexia lasting a couple of days is to be expected. The unpleasant smell which develops can be kept in check by means of "deodorizing bags". If these are not available it may be necessary to change the cast every two to four weeks in hot countries. When a change of plaster is required, the patient is anæsthetized, and full aseptic precautions are observed; care is also taken to avoid movement of the fragments. If radiographs show that there is overriding of the fragments, then skeletal traction should be used at the changing of the plaster, and the pins should be incorporated into the cast. If angulation occurs, it can be corrected by wedging the plaster.

Every time the cast is removed, the purulent or necrotic tissue should be gently irrigated from the wound with warm normal saline solution. Crystals of a sulphonamide should then be sprinkled over the wound. It is ineffective to dust the crystals onto pus or necrotic tissue.

The complications of compound fractures most likely to develop during the closed plaster treatment are as follows: (*a*) Localized infection may occur owing to inadequate drainage of some part of the wound. The patient's temperature rises and localized pain is felt. The cast must be removed and drainage instituted, after which a further cast is applied. (*b*) Septic dermatitis may result from the action of pus on the skin surrounding the wound. This is not so liable to occur if "Vaseline" is used to protect the skin. It can be treated by giving a few days' interval before the application of a fresh plaster. (*c*) Secondary hæmorrhage is denoted by sudden pain followed by a rise of pulse rate, together with pallor, sweating, and perhaps a fall in blood pressure. The plaster must be removed and the bleeding vessel tied. Blood transfusion may be necessary. (*d*) An unduly tight plaster may cause constriction of the circulation. In the early stages this can be treated by "springing" the plaster. If this is unsuccessful the cast has to be removed and a fresh one applied. (*e*) Gas gangrene is to be suspected if the pulse rate rises and the patient has general signs and symptoms such as pain, sleeplessness, anorexia, restlessness and dry tongue. It usually comes on within the first two or three days. The plaster must be removed as soon as the presumptive diagnosis is made. If the diagnosis is confirmed, affected muscles must be excised. The only feasible way of doing this in some cases is to amputate the limb. Gas gangrene antiserum is also given, and use is made of either sulphonamide or X-ray therapy. It is said that gas gangrene is about six times as common in compound fractures as it is in soft tissue injuries, but this may merely be a reflection of the greater severity of the former injury. (*f*) Tetanus is an occasional complication, mostly in those who have been neither immunized nor passively protected by antiserum. To treat the condition, the specific antiserum is given intravenously, the spasms are controlled by sedatives, and the nutrition is maintained.

AMPUTATION.

There is justifiable hesitation before a limb is amputated for a compound fracture. It is especially important to be conservative about amputation of the upper limbs. In regard to the upper limbs even considerable shortening is of minor importance, gas gangrene is comparatively rare, shock is seldom a complication, infected phlebitis and embolism are extremely rare, vascular damage is not so critical, and the best upper limb prostheses are almost useless. In the case of neither limb should one amputate merely on account of gross contamination, extensive comminution or loss of large areas of skin. The following have been suggested as a rough guide to the circumstances in which it is usually wise to amputate immediately for projectile fractures of the femur: (*a*) when the femoral or popliteal vessels are wounded; (*b*) when the condyles are comminuted and the knee joint is involved; (*c*) when large portions of muscle have been torn off, so that the limb would be useless, even if it were preserved.

Immediate amputation can be done as a formal flap amputation at the site of election. Prophylactic chemotherapy is given and the risk of infection is little greater than that following primary excision of a wound.

Late amputation is sometimes indicated following compound fractures, and the technique required is different. The indications for this type of amputation are: massive gas gangrene, gangrene due to vascular occlusion, repeated secondary hæmorrhages, and spreading infection with severe toxæmia.

It is in regard to late amputation of the thigh that proper conservatism is most likely to start an attitude which drifts on into one of harmful procrastination. It is therefore an advantage to remember that amputation of these grossly wasted limbs is easily and quickly performed, and the small amount of shock caused is readily treated.

In cases of late amputation, some infection at the amputation site is almost inevitable. The operation of choice is a guillotine amputation well below the site of election. This deals with the factor of infection; and, after several weeks, when the granulating surface has become clean and dry and œdema has subsided, a formal flap amputation is performed at the site of election.

If the amputation has to be performed at the site of election or slightly above it, then a flap amputation is done, provided that there is viable skin extending further distally. The flaps must not be sutured together until seven to ten days have elapsed.

RESULTS OF TREATMENT OF COMPOUND FRACTURES.

It is a general rule that compound fractures unite slowly and occasionally not at all. Non-union is much more frequent in compound fractures than in simple fractures. Winnett Orr has gathered figures "from many sources" and shown that amputations or deformity or permanent incapacity for work follow nearly 50% of all compound fractures.[6]

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